Similarities and Differences Between Sexes and Countries in the Mortality Imprint of the Smoking Epidemic in 34 Low-Mortality Countries, 1950-2014

Janssen, Fanny

Published in:
Nicotine & Tobacco Research

DOI:
10.1093/ntr/ntz154

Nicotine & Tobacco Research, 2020, 1210–1220
doi:10.1093/ntr/ntz154
Original investigation
Received March 20, 2019; Editorial Decision August 12, 2019; Accepted August 21, 2019

SRNT

OXFORD

Original investigation

Similarities and Differences Between Sexes and Countries in the Mortality Imprint of the Smoking Epidemic in 34 Low-Mortality Countries, 1950–2014

Fanny Janssen PhD[1,2]

[1]Population Research Centre, Faculty of Spatial Sciences, University of Groningen, Groningen, The Netherlands; [2]Netherlands Interdisciplinary Demographic Institute, The Hague, The Netherlands

Corresponding Author. Fanny Janssen, PhD, Population Research Centre, Faculty of Spatial Sciences, University of Groningen, P.O. Box 800, 9700 AV Groningen, The Netherlands. E-mail: f.janssen@rug.nl

Abstract

Introduction: The smoking epidemic greatly affected mortality levels and trends, especially among men in low-mortality countries. The objective of this article was to examine similarities and differences between sexes and low-mortality countries in the mortality imprint of the smoking epidemic. This will provide important additions to the smoking epidemic model, but also improve our understanding of the differential impact of the smoking epidemic, and provide insights into its future impact.

Methods: Using lung-cancer mortality data for 30 European and four North American or Australasian countries, smoking-attributable mortality fractions (SAMF) by sex, age (35–99), and year (1950–2014) were indirectly estimated. The timing and level of the peak in $SAMF_{35\text{-}99}$, estimated using weighting and smoothing, were compared.

Results: Among men in all countries except Bulgaria, a clear wave pattern was observed, with $SAMF_{35\text{-}99}$ peaking, on average, at 33.4% in 1986. Eastern European men experienced the highest (40%) and Swedish men the lowest (16%) peak. Among women, $SAMF_{35\text{-}99}$ peaked, on average, at 18.1% in 2007 in the North American/Australasian countries and five Northwestern European countries, and increased, on average, to 7.5% in 2014 in the remaining countries (4% in Southern and Eastern Europe). The average sex difference in the peak is at least 25.6 years in its timing and at most 22.9 percentage points in its level.

Conclusions: Although the progression of smoking-attributable mortality in low-mortality countries was similar, there are important unexpected sex and country differences in the maximum mortality impact of the smoking epidemic driven by cross-country differences in economic, political, and emancipatory progress.

Implications: The formal, systematic, and comprehensive analysis of similarities and differences between sexes and 34 low-mortality countries in long-term time trends (1950–2014) in smoking-attributable mortality provided important additions to the Global Burden of Disease study and the descriptive smoking epidemic model (Lopez et al.). Despite a general increase followed by a decline, the timing of the maximum mortality impact differs more between sexes than previously anticipated, but less between regions. The maximum mortality impact among men differs considerably between countries. The observed substantial diversity warrants country-specific tobacco control interventions and increased attention to the current or expected higher smoking-attributable mortality shares among women compared to men.

Introduction

The smoking epidemic is currently most advanced in low-mortality countries, where it continues to have large social and economic effects, including increased levels of suffering, disease, death and associated productivity losses, and health care costs.[1] The impact of smoking on all-cause mortality levels, all-cause mortality trends, and differences therein between countries and sexes is well documented for low-mortality countries.[2–9]

As illustrated by the descriptive smoking epidemic model, the timing of the smoking epidemic has differed substantially between sexes and low-mortality countries.[10,11] Among men, smoking was taken up first in Anglo-Saxon and Northwestern European countries, and an average of 25 years later in Southern and Eastern Europe. Women, in general, took up smoking about two decades later than men, and their smoking prevalence levels remained lower than the high levels observed among men. Specifically, the maximum smoking prevalence ranged from 50% to 80% for men and around 35%–45% for women. However, all countries and both sexes display a similar pattern, whereby smoking-attributable mortality increased and then declined about 30–35 years after the initial increase and subsequent decline in smoking prevalence. The peak in smoking-attributable mortality is expected to occur about 20 years later for women than for men, and to reach maximum levels of 20%–25% among women and 30%–35% among men. Countries where the smoking epidemic started later may be able to introduce effective preventive interventions during an earlier phase of the smoking epidemic, and thus to have lower maximum levels of smoking-attributable mortality than countries in later phases of the smoking epidemic.

However, the exact timings and levels of the full mortality imprint of the smoking epidemic are, as yet, unknown. Let alone, differences between sexes and low-mortality countries in these timings and levels. Numerous studies have examined the progression of the smoking epidemic while using either smoking prevalence[12–14]or lung cancer mortality[15–19] as the outcome measure. The Global Burden of Disease study provides global, regional, and national estimates of smoking prevalence, smoking-attributable deaths, and smoking-attributable disease burden from 1990 onward.[20,21] The few existing studies on more long-term trends in smoking-attributable mortality only included a few low-mortality countries.[10,22] None of the earlier-mentioned studies however performed a formal and systematic analysis of country- and sex differences in the timing and level of the progression of smoking-attributable mortality.

Such a systematic analysis, however, can not only improve our understanding of the differences in the mortality impact of the smoking epidemic between countries and sexes, but its outcomes could also be used to estimate the future impact of the smoking epidemic in low-mortality countries. Although the smoking epidemic is most advanced in low-mortality countries, it is expected to have an important imprint on population health for many years to come, particularly among women.[22–25]

This article systematically examines similarities and differences between sexes and 34 low-mortality countries in the mortality imprint of the smoking epidemic, and particularly in the level and timing of the maximum mortality impact.

Data and Methods

Data and Setting

The analysis includes the national populations of 30 European countries, United States, Canada, Australia, and New Zealand, by sex and age (35–99), for the period 1950–2014.

Lung cancer mortality deaths by age (35–39, …. 75–79, 80+), country, sex, and calendar year were retrieved from the WHO Mortality Database, updated April 11, 2018.[26] All-cause mortality deaths and exposure data for the corresponding populations were retrieved from HMD, downloaded September 29, 2018.[27] When necessary, additional lung cancer mortality data were used or additional calculations were applied. See Appendix I for the data and years used by country.

The countries were organized into six main groups: North American/Australasian countries (Australia, Canada, New Zealand, United States), Northern Europe (Denmark, Finland, Norway, Sweden), Western Europe (Austria, Belgium, France, Germany (west), Iceland, Ireland, Luxembourg, Netherlands, Switzerland, United Kingdom), Southern Europe (Greece, Italy, Portugal, Spain), Central Europe (Czech Republic, Germany (east), Hungary, Poland, Slovakia, Slovenia), and Eastern Europe (Belarus, Bulgaria, Estonia, Latvia, Lithuania, Ukraine, Russia).

Smoking-Attributable Mortality Fractions

For each country and year, age (x)- and sex (s)-specific smoking-attributable mortality fractions ($SAMF_{x,s}$) were estimated by applying a simplified indirect Peto–Lopez method.[23,28] The Peto–Lopez method indirectly estimates smoking prevalence based on—predominantly—country-level observed lung cancer mortality rates, and subsequently applies the standard epidemiological population-attributable fraction formula and Relative Risks (RRs) of dying from smoking to estimate smoking-attributable mortality. Whereas the original Peto–Lopez method does so by cause of death, the simplified version does so for all causes combined. The method takes into account that not all lung cancer deaths are attributable to smoking and includes deaths from other causes that could be attributed to smoking.

First, the lifetime smoking prevalence (p) by 5-year age groups and sex was indirectly estimated based on country-, age- and sex-specific lung cancer mortality rates while controlling for lung cancer mortality that is not because of smoking. This was done by comparing the country-specific rates with the aggregated age- and sex-specific lung cancer rates of smokers and never-smokers (smoothed) in the ACS CPS-II study.[28] Subsequently, the sex-specific lifetime smoking prevalence by single year of age was obtained by Loess smoothing.

Second, the share of all-cause mortality because of smoking (SAMF) was calculated by: $SAMF_{x,s} = p_{x,s}\,(RR_{x,s}-1)/(p_{x,s}\,(RR_{x,s}-1)+1)$, where $p_{x,s}$ reflect the obtained sex-specific estimates of the lifetime smoking prevalence by single year of age, and $RR_{x,s}$ reflect the relative risks of dying from smoking by single year of age and sex. RRs by 5-year age groups (35–39, 40–44, …, 80–84, 85+) and sex were obtained by dividing the respective all-cause mortality rates among CPS-II current smokers by the respective all-cause mortality rates among CPS-II never smokers.[29] To control for the exposure of smokers to other risk factors, the excess risk was reduced by 30%.[30] We obtained the RRs by single year of age by applying a second-degree polynomial thereby keeping the RRs stable from age 90 onward for men and from age 87 onward for women.

The subsequent Loess smoothing over age of the $SAMF_{x,s}$ led to a negligible difference in the overall estimate of the impact of smoking on mortality.

Analysis

To determine the year in which the impact of smoking was greatest, SAMFs across ages 35–99 ($SAMF_s$) were obtained by weighting the $SAMF_{x,s}$ by age-specific death numbers for each sex, year, and country. Subsequently, the trends in $SAMF_s$ over time were smoothed and the maximum of this smoothed trend was obtained. This procedure proved more accurate than first applying either age-period or age-period-cohort models to the data, and then obtaining the maximum from these models.

Smoothing of the $SAMF_s$ involved Loess smoothing with—in general—span 0.75 and degree 2. To improve the fit, a span of 0.5 was used for Australian, Canadian, French, and Spanish women; and a span of 1.5 for Icelandic men. For Latvia and Lithuania, a span of 2.0 and degree 1 was used to avoid focusing too much attention on the existing fluctuations. Appendix II illustrates that the smoothing we applied nicely captures the trend over time while ensuring that the year in which the maximum is reached is not influenced by fluctuations.

Results

Looking at the trends in smoothed smoking-attributable mortality fractions over ages 35–99 (referred to as SAMF from here onward) from 1950 to 2014 (Figure 1; Supplementary Figure 1), among men a clear wave pattern of an increase followed by a decline in all countries except Bulgaria can be observed. Among women, an increase followed by a peak and—in most cases—a subsequent decline was observed in the four North American/Australasian countries and five Northwestern European countries (Denmark, Norway, Iceland, Ireland, United Kingdom) (see as well Figure 2); and an upward trend in SAMF was observed in most of the remaining countries. For women in Belarus, Russia, and Ukraine, SAMF levels have been consistently low, and a peak occurred earlier than among men. Among Bulgarian men and women, minimal declines in SAMF levels were observed. Because the observed maxima in these five instances most likely do not depict the actual peak of the smoking epidemic, they were disregarded.

Among men, the peak in SAMF was, on average, reached in 1986, at 33.4% (Table 1). SAMF peaked early among men in North American/Australasian and Northwestern European countries (1980, on average) but also in the Czech Republic (1977) (Table 1; Figure 2; Supplementary Table 1). In the majority of these countries, men also experienced high maximum levels (on average, 32% in North American/Australasian countries and Western European countries and 27% in Northern European countries) (see also Figure 3). Men in Central and Eastern European (CEE) countries experienced, on average, the highest maximum SAMF (39%), albeit at a later point in time (1993). Men in Southern European countries experienced, on average, the peak as late as men in the Central European countries (1991), and had the lowest maximum level (26.1%, on average). Among men, the maximum SAMF was highest among men in Russia (44.4%) and Finland (41.9%), and was more than 40% in the United Kingdom, Hungary, and Estonia, and was lowest in Sweden (16.0%) and Portugal (17.9%), followed by in Iceland (18.5%) and Norway (18.8%).

Among women, the maximum SAMF in the North American/Australasian and Northwestern European countries was, on average, reached in 2013, at 18.1%. Women in Denmark had the highest peak, at 22.5%, whereas women in Australia had the lowest peak, at 12% (Table 1; Figure 3; Supplementary Table 1). In the remaining Northwestern European countries in which SAMF is still increasing, the average level reached among women in 2014 was around 10%. The exceptions are women in Hungary and the Netherlands, who reached high SAMF levels in 2014 (17.9% and 15.6%, respectively). Among women in Southern and Eastern Europe, the SAMF reached values of only around 4%. The lowest SAMF levels among women were in Belarus (1.6%), followed by Portugal, Lithuania, and Spain (2.3%–2.5%).

The average difference between men and women in the timing of the peak was 24.2 years (unweighted average) for the nine countries in which the peak has already been reached among women (Table 1). In the North American/Australasian countries, this difference was even slightly higher, at 25.8 years. Across all countries, the minimum sex difference in the timing was 25.6 years. On average, the difference was at least 36.4 years for the nine remaining Northwestern European countries, at least 23 years in Central and Southern Europe, and at least 16.3 years in Eastern Europe. Figure 2 clearly depicts this general pattern but also shows important exceptions for individual countries, including Iceland (15 years' difference) and the Czech Republic (37 years' difference).

The maximum level of SAMF was, on average, 11.6 percentage points lower among women than among men in the nine countries for which the peak among women has already been reached (Table 1; Figure 3). The sex difference was greater in the four North American/Australasian countries than in the two Northern European countries

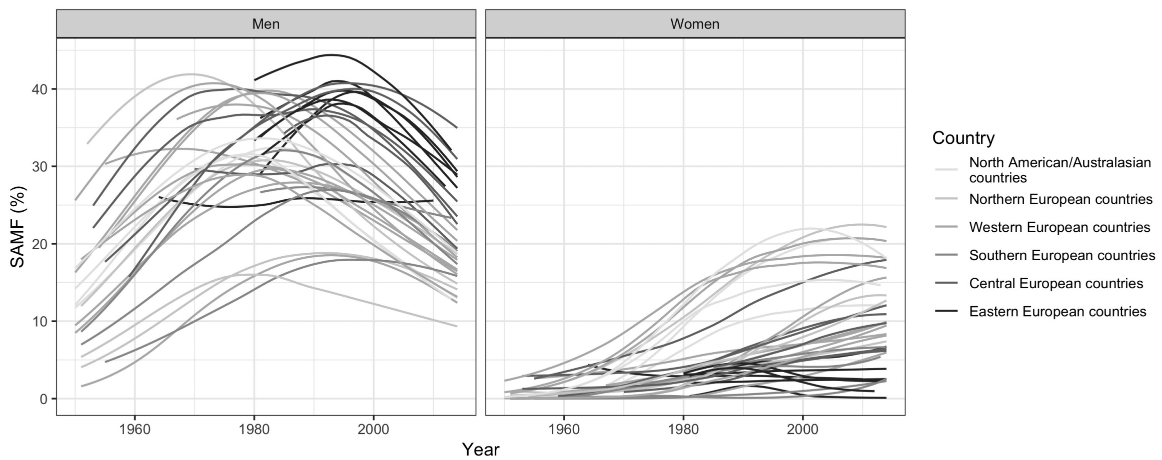


Figure 1. Trends over time in the smoothed smoking-attributable mortality fractions (SAMF) over ages 35–99, 4 North American/Australasian countries and 30 European countries, 1950–2014*, by region and sex. *Or latest available year: Bulgaria (2010), Canada (2011), Greece (2013), New Zealand (2013), Ukraine (2012), Russia (2013). North American/Australasian countries = Australia, Canada, New Zealand, USA. Northern European countries = Denmark, Finland, Norway, Sweden. Western European countries = Austria, Belgium, United Kingdom, France, West Germany, Iceland, Ireland, Luxembourg, Netherlands, Switzerland, United Kingdom. Southern European countries = Greece, Italy, Portugal, Spain. Central European countries = Czech Republic, East Germany, Hungary, Poland, Slovakia, Slovenia. Eastern European countries = Belarus, Bulgaria, Estonia, Latvia, Lithuania, Ukraine, Russia.

Table 1. The Average Timing and Level of the Peak in Smoothed Smoking-Attributable Mortality Fractions (SAMF) Over Ages 35–99, 4 North American/Australasian Countries and 30 European Countries, 1950–2014*, by Region and Sex

(a) Unweighted average of the level of the peak in SAMF (%)

						Men – women for those countries for which max among women has been reached (in % points)		Men – women for those countries for which max among women has not yet been reached (in % points)		Men – women for all countries (in % points)	
Region	Men	Men#	Women	Women#	Women@	M – W	*N*	M – W	*N*	M – W	*N*
All countries	33.2	33.4	10.3	18.1	7.5	11.6	9	26.9	25	22.9	34
N. America/Australasia	32.2	32.2	17.5	17.5	NA	14.7	4	NA	NA	14.7	4
Northern Europe	26.9	26.9	14.0	17.9	10.0	6.9	2	18.9	2	12.9	4
Western Europe	32.6	32.6	12.4	19.0	9.6	10.7	3	24.2	7	20.1	10
Southern Europe	26.1	26.1	4.2	NA	4.2	NA	NA	21.9	4	21.9	4
Central Europe	37.5	37.5	10.5	NA	10.5	NA	NA	27.0	6	27.0	6
Eastern Europe	38.2	40.3	3.9	NA	3.9	NA	NA	34.3	7	34.3	7

(b) Unweighted average of the year of the peak in SAMF

						Women – men for those countries for which max among women has been reached (in years)		Women – men for those countries for which max among women has not yet been reached (in years)		Women – men for all countries (in years)	
Region	Men	Men#	Women	Women#	Women@	W - M	*N*	W - M	*N*	W - M	*N*
All countries	1986.3	1985.5	2011.9	2006.9	2013.7	24.2	9	26.1	25	25.6	34
N. America/Australasia	1980.0	1980.0	2005.8	2005.8	NA	25.8	4	NA	NA	25.8	4
Northern Europe	1980.8	1980.8	2012.8	2011.5	2014.0	24.0	2	40.0	2	32.0	4
Western Europe	1980.0	1980.0	2011.4	2005.3	2014.0	22.3	3	35.3	7	31.4	10
Southern Europe	1990.8	1990.8	2013.8	NA	2013.8	NA	NA	23.0	4	23.0	4
Central Europe	1990.8	1990.8	2014.0	NA	2014.0	NA	NA	23.2	6	23.2	6
Eastern Europe	1996.7	1994.5	2013.0	NA	2013.0	NA	NA	16.3	7	16.3	7

*Or latest available year: Bulgaria (2010), Canada (2011), Greece (2013), New Zealand (2013), Ukraine (2012), Russia (2013).
#Only those countries for which the max has already been reached. For men in all countries except Bulgaria. For women in Australia, Canada, New Zealand, USA, Denmark, Norway, Iceland, Ireland, United Kingdom (*N* = 9).
@Only those countries for which the max has not yet been reached.

(14.7 compared to 6.9 percentage points). Across all countries, the maximum average sex difference in the SAMF level is 22.9 percentage points. The maximum average sex difference was smallest in the remaining Northern European countries, at 18.9 percentage points; followed by Southern Europe (21.9), Western Europe (24.2), Central Europe (27), and Eastern Europe (34.3).

Discussion

Summary of Results

Among men, a clear wave pattern was observed in all 34 low-mortality countries except Bulgaria, with SAMF peaking, on average, at 33.4% in 1986. Among women, SAMF in the four North American/Australasian countries and in Denmark, Iceland, Ireland, Norway, and the United Kingdom peaked, on average, at 18.1% in 2007—in line with the early peak among men in these country groups. Among women in the remaining countries, SAMF is increasing, and reached, on average, 7.5% in 2014. The (maximum) mortality impact was greatest among men in most CEE countries (especially Russia, at 44%) and among women in Denmark (22.5%) and was smallest among men in Sweden (16%) and among women in Southern and Eastern Europe (4% in 2014). The average observed difference between women and men in the year in which the maximum was reached was 24.2 years, with a minimum of 25.6 years for all countries. The average observed sex difference in the maximum level of SAMF was 11.6 percentage points, with a maximum of 22.9 percentage points for all countries.

Comparison to Previous Research

The reported sex-specific estimates of the exact timings and levels of the peak in smoking-attributable mortality fractions for European regions and individual European and North American/Australasian countries are novel in the context of the previous research outlined in the Introduction section.

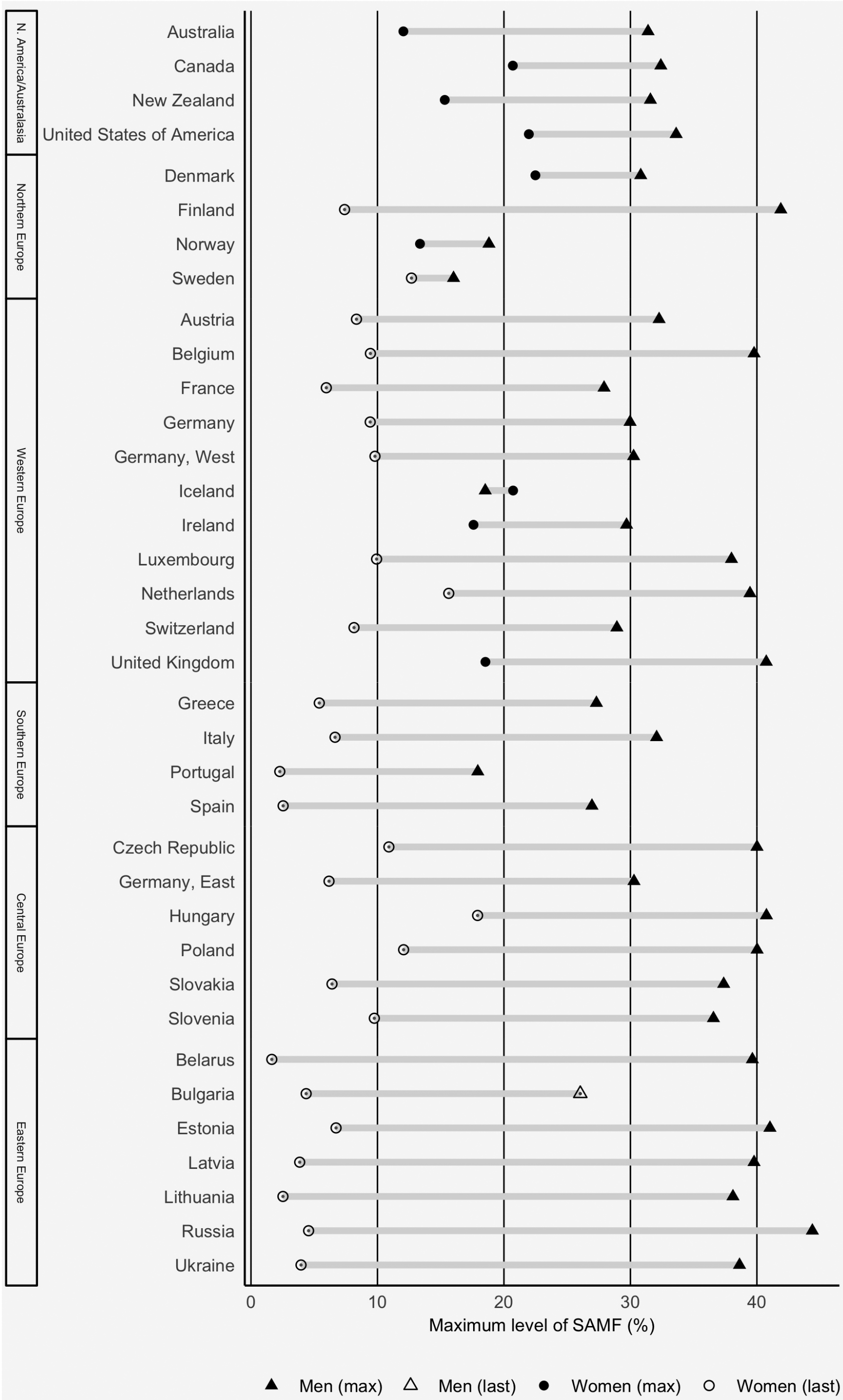


Figure 2. Sex differences in the timing of the peak in the smoothed smoking-attributable mortality fractions (SAMF) over ages 35–99, 4 North American/Australasian countries and 30 European countries, 1950–2014*. *Or latest available year: Bulgaria (2010), Canada (2011), Greece (2013), New Zealand (2013), Ukraine (2012), Russia (2013).

The estimates support the more general statements on the timing and levels of the peaks for different regions in the smoking epidemic model by Lopez et al..[11] These estimates show a general (indication of) a wave-shaped pattern over time; a clear distinction in the timing of the maximum mortality impact between the North American/Australasian countries and North-western European countries on the one hand (early), and the Southern and Eastern European countries on the other (late); and the existence of important differences between sexes in the timing and level of the smoking epidemic.

Important additional observations include smaller differences between regions in the timing of the maximum mortality impact; a greater maximum mortality impact among men, with considerable diversity between countries; and larger sex differences in the timing of the maximum mortality impact.

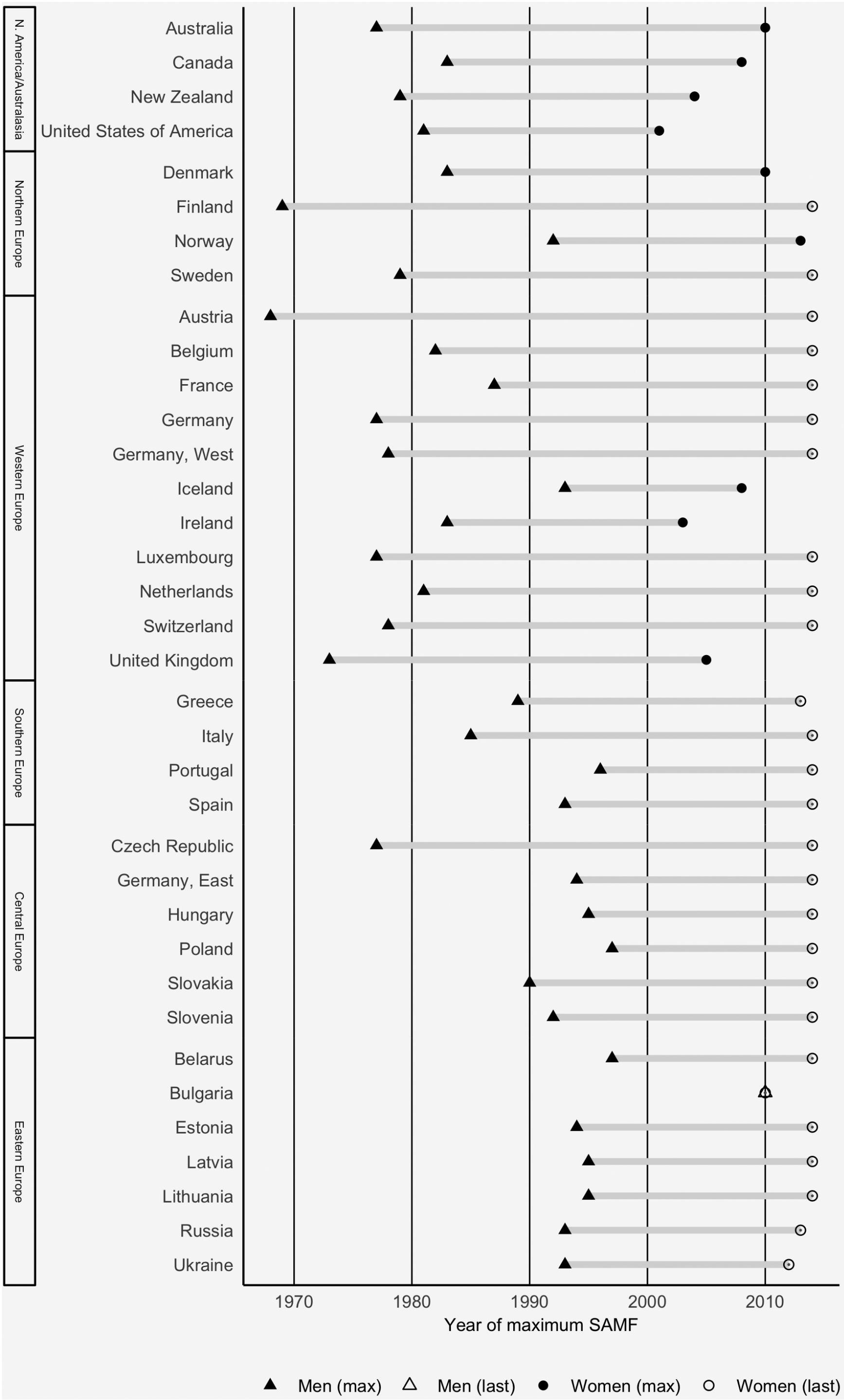


Figure 3. Sex differences in the level of the smoothed smoking-attributable mortality fractions (SAMF) over ages 35–99, 4 North American/Australasian countries and 30 European countries, 1950–2014*. *Or latest available year: Bulgaria (2010), Canada (2011), Greece (2013), New Zealand (2013), Ukraine (2012), Russia (2013).

The current analysis reveals that, on average, the maximum impact was reached in 1980 for the North American/Australasian countries and Northwestern European countries, and in 1993 for the Southern and Eastern European countries. This difference is smaller than the 25-year difference obtained in the smoking-epidemic model—although their comparison also included Latin America, where, on average, the smoking epidemic started later than in Southern and Eastern Europe.[31]

The maximum mortality impact of smoking was highest among men in Eastern Europe, particularly in Russia, at 44.4%; and among women in Denmark, at 22.5%. These findings are in line with the maximum smoking-attributable mortality of 20%–25% for women in the smoking epidemic model but are considerably higher than the maximum of 30%–35% for men.

The reported sex differences in the timing of the maximum mortality impact (24 years for the nine countries with a peak among women; a minimum of 26 years for all countries; 36 years for the remaining nine Northwestern European countries) exceed the 20-year difference suggested in the smoking epidemic model.[11] At that point in time, it was difficult to make such an assumption since the peak for women had not yet been reached. The follow-up article in 2012[10] reported important differences for the four countries under study.

The average sex difference in the maximum level of SAMF of 11.6 percentage points for the nine countries in which a maximum for women has already been observed is in line with the suggested difference in the smoking epidemic theory of around 10 percentage points (30%–35% among men, 20%–25% among women).[11] The average sex difference for all countries under study is likely to become substantially smaller than the current maximum difference of 22.9 percentage points because of the projected increase in smoking-attributable mortality among women in future years.

Clearly important—partly unanticipated—diversity between countries and sexes in the mortality imprint of the smoking epidemic exists.

Explanation of Observed Results

The observed country differences in the timing of the maximum impact can, above all, be linked to differences in the onset of the smoking epidemic resulting from differences in economic development.

The high-income levels in North American/Australasian and most Northwestern European countries facilitated the early automation of the cigarette production process and the uptake of smoking by men.[11,32,33]. As a result, these countries experienced an early onset of the smoking epidemic leading to the observed early timing of the maximum impact of smoking among men and the observation of a maximum impact of smoking among women in these countries only.

Conversely, in Southern and Eastern European countries, where the smoking epidemic started later because of delays in economic development,[32] the maximum impact of smoking occurred later among men, and has yet to reach a peak among women.

The observed important country differences in the maximum mortality impact among men can be linked, above all, to differences in contextual circumstances and in the awareness of the negative health consequences of smoking.

The high share of mortality because of smoking in Eastern Europe[2,28,30] has been attributed to the unfavorable economic, political, and health conditions in these countries, especially for men.[34] The SAMF levels of 44% in Russia and 40% in Eastern Europe are in line with past smoking prevalences of more than 60% and around 50%–55%, respectively.[35,36]

The high impacts among men in Finland (41.9%), the United Kingdom (40.7%), and Belgium (39.8%) can partly be related to the early onset of the smoking epidemic in these countries, in a context in which knowledge of the negative effects of smoking was not widespread, and the potential for the initiation of effective preventive policies was therefore lower.[11,32] Indeed, compared to the North American/Australasian countries, there was less awareness of the health risks of smoking in these countries.[32,37]

The low maximum mortality impact in Portugal (and Spain) may be explained by the late onset of the smoking epidemic and the low GDP, which prevented the widespread diffusion of the smoking epidemic.[32] Among Swedish men, the high prevalence of smokeless tobacco (snus) has played an important role.[38]

The high smoking impact among Danish women can be related to their early uptake of smoking, and high historical smoking prevalence and smoking-attributable mortality.[39] Explanations include the broad acceptance in Denmark of smoking among women as a social activity, and smoking being a strategy for coping with stress because of heavy workloads and deteriorating living conditions at the time.[40]

The observed important sex differences in the timing and the level of the (maximum) mortality impact can be linked to sex differences in smoking prevalence about 30–40 years earlier.[41] This sex differential in smoking prevalence can be explained by men, in general, being more prone to take up risky behaviors than women.[42] As the position of women in society changed with the rise in women's labor force participation,[43] and as cultural prohibitions against smoking among women were challenged during periods of war and (political) liberalization,[10] women started taking up smoking several decades after men.[11] Because, by that time, the negative effects of smoking on health were much more known, smoking among women never reached the enormously high levels observed among men.

The observed important country differences in the sex difference in the timing and the level of the (maximum) mortality impact could point to country differences in the interaction of socioeconomic, cultural, and material circumstances with emancipatory factors.[43]

Important to note is that, because the timing of the maximum level differs between men and women, in some countries women now have similar or higher smoking-attributable mortality fractions than men. Supplementary Figure 1 clearly shows that this is currently the case for Australia, Canada, Denmark, Iceland, Ireland, New Zealand, Norway, Sweden, the United Kingdom, and the United States; and soon will be the case for a wide range of Northwestern European countries. The other European countries are likely to follow, with the probable exception of most Eastern European countries, where SAMF levels among men are highest and SAMF levels among women have remained very low in recent years.

Evaluation of Data and Methods

In this article—and in line with most previous research—an indirect method for estimating smoking-attributable mortality was used to avoid relying on incomplete detailed historical smoking prevalence data, to facilitate the use of high-quality cause-of-death information, and to capture the effects not only of smoking prevalence, but of smoking duration and smoking intensity.[44,45] The Global Burden of Disease (GBD) study, till last year, also relied—albeit solely for cancers and chronic respiratory diseases—on an indirect method.[20,21]

As an indirect approach, in the current analysis, an adapted simpler version of the Peto–Lopez method is used.[23,28] This is because, the Peto–Lopez method has been widely used in the field, among which in the GBD study.[5,20,25] The adapted version requires even less information while leading to similar outcomes. More recently, a regression-based indirect method has been developed by Preston, Glei, and Wilmoth, leading as well to different variants.[46,47] Although these methods will result in slightly different estimates,[22] the timing of the peak of the mortality impact will hardly be affected.

Some assumptions underlying the adapted Peto–Lopez method are important to consider.

First, the estimates of smoking-attributable mortality rely heavily on the RRs of dying from smoking from the ACS-CPSII study in 1982–1988. The sex difference in RRs in this study (2.25 for men; 1.72 for women) will therefore partly determine the sex difference in smoking-attributable mortality. Because the RRs are not country-specific, the country differences in the mortality impact of smoking are likely underestimated, because populations differ in their risk of dying from smoking. The use of a time-independent RRs could influence the timing of the maximum impact of smoking, but the sex and the country differences in the timing of the maximum impact of smoking would remain largely unaltered.

Second, country differences in smoking-attributable mortality are likely affected by the assumption of the same ratio for each country between background lung cancer mortality (lung cancer mortality not because of smoking) and smoking-attributable lung cancer mortality.[48] However, especially in CEE countries, lung cancer mortality is likely affected to a certain extent by environmental factors, like air contamination and exposure to hazardous occupational agents.[49]

Thus, whereas the observed sex and country differences in the timing of the maximum mortality impact of the smoking epidemic seem rather robust, the (maximum) SAMF values and their comparison across countries are affected by the method used to estimate smoking-attributable mortality. Caution is therefore warranted. However, the observed differences between countries and sexes in smoking-attributable mortality fractions seem largely in line with respective differences in smoking prevalence around 1980.[13,36,50] Also, it is important to note that when attempting to study smoking-attributable mortality over an extended period of time, reliance on an indirect estimation method is a necessity.

Conclusions and Implications

The systematic analysis of long-term time trends (1950–2014) in smoking-attributable mortality in 34 low-mortality countries revealed clear similarities and differences between sexes and countries in the mortality imprint of the smoking epidemic.

The general observed (indications of a) wave pattern in smoking-attributable mortality, combined with population-specific evidence on the current phase in the progression of the epidemic, provide clear indications of the future progression of the smoking epidemic. Among men, the impact on mortality will further decline, possibly at a reduced rate that will start first in North American/Australasian and Northwestern European countries. Among women, the maximum mortality impact is expected to be reached relatively soon in Sweden, the Netherlands, Switzerland, Finland, Austria, Germany, Luxembourg, Italy, the Czech Republic, and Hungary; based on either a deceleration of the current increase in SAMF or (increasingly) small differences in SAMF levels between men and women. Among women in the remaining, mostly CEE countries, SAMF levels could continue to rise for another 20 years, given the increasing trends in smoking prevalence up to 2005.[13,20,36]

The observed considerable diversity between countries and sexes, driven by country differences in the economic, political, and emancipatory progress, clearly points to the importance of country-specific tobacco control interventions. Although lessons can certainly be learned from good practice in the forerunner countries, an adjustment to fit the specific national context seems appropriate as well. Increased attention for the current or expected higher shares of mortality because of smoking among women compared to men is warranted as well.

Supplementary Material

Supplementary data are available at *Nicotine and Tobacco Research* online.

Funding

This work is funded by the Netherlands Organisation for Scientific Research (NWO) in relation to the research program "Smoking, alcohol, and obesity, ingredients for improved and robust mortality projections", under grant no. 452-13-001. See www.futuremortality.com. The funding source had no role in the study design, collection, analysis, or interpretation of the data; in writing the manuscript; or in the decision to submit the article for publication.

Conflict of Interests

None declared.

Acknowledgments

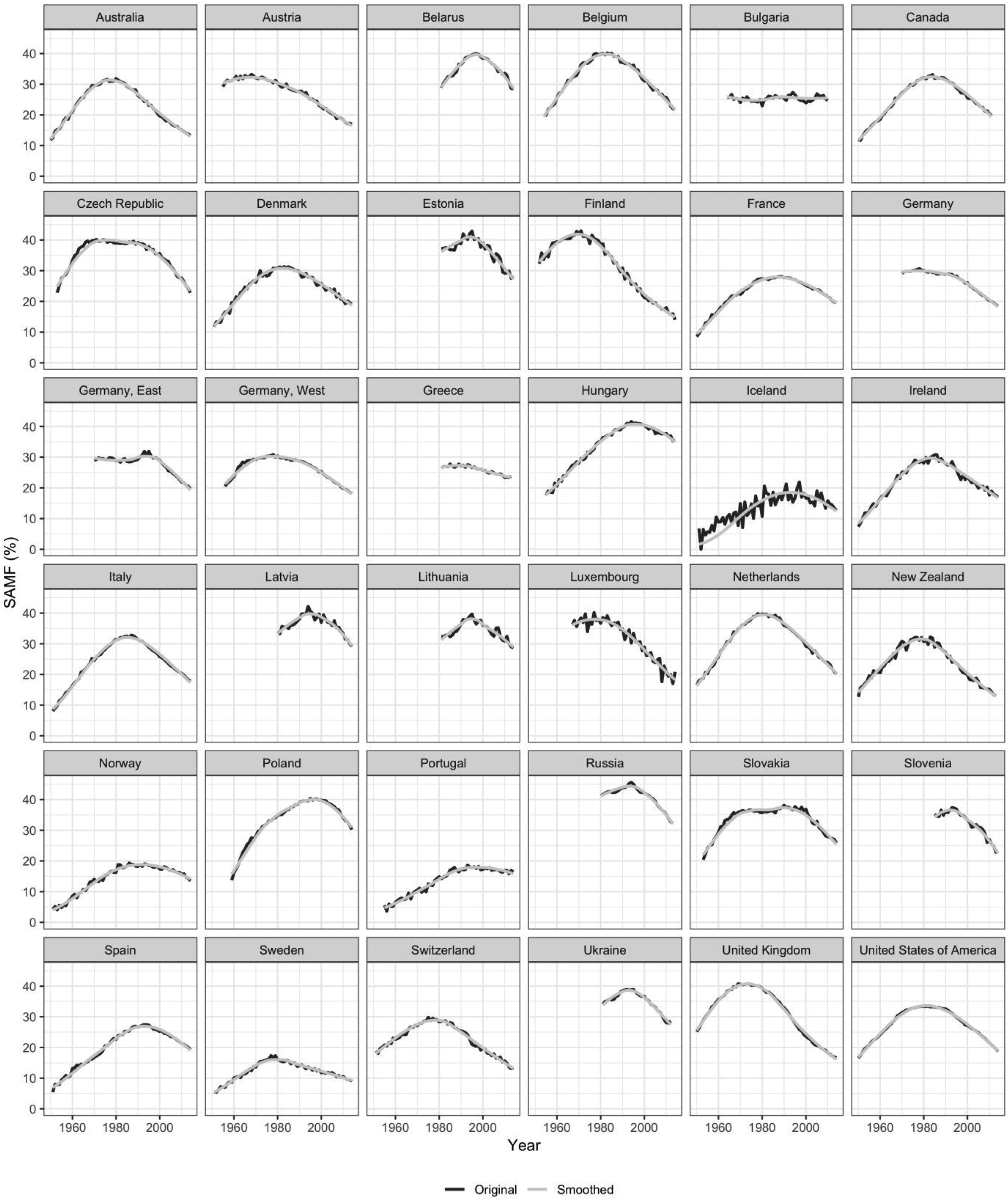
I thank Mark van der Broek (econometrics, University of Groningen) for running the analyses in R.

Appendix I. Countries included in the analysis and their data availability

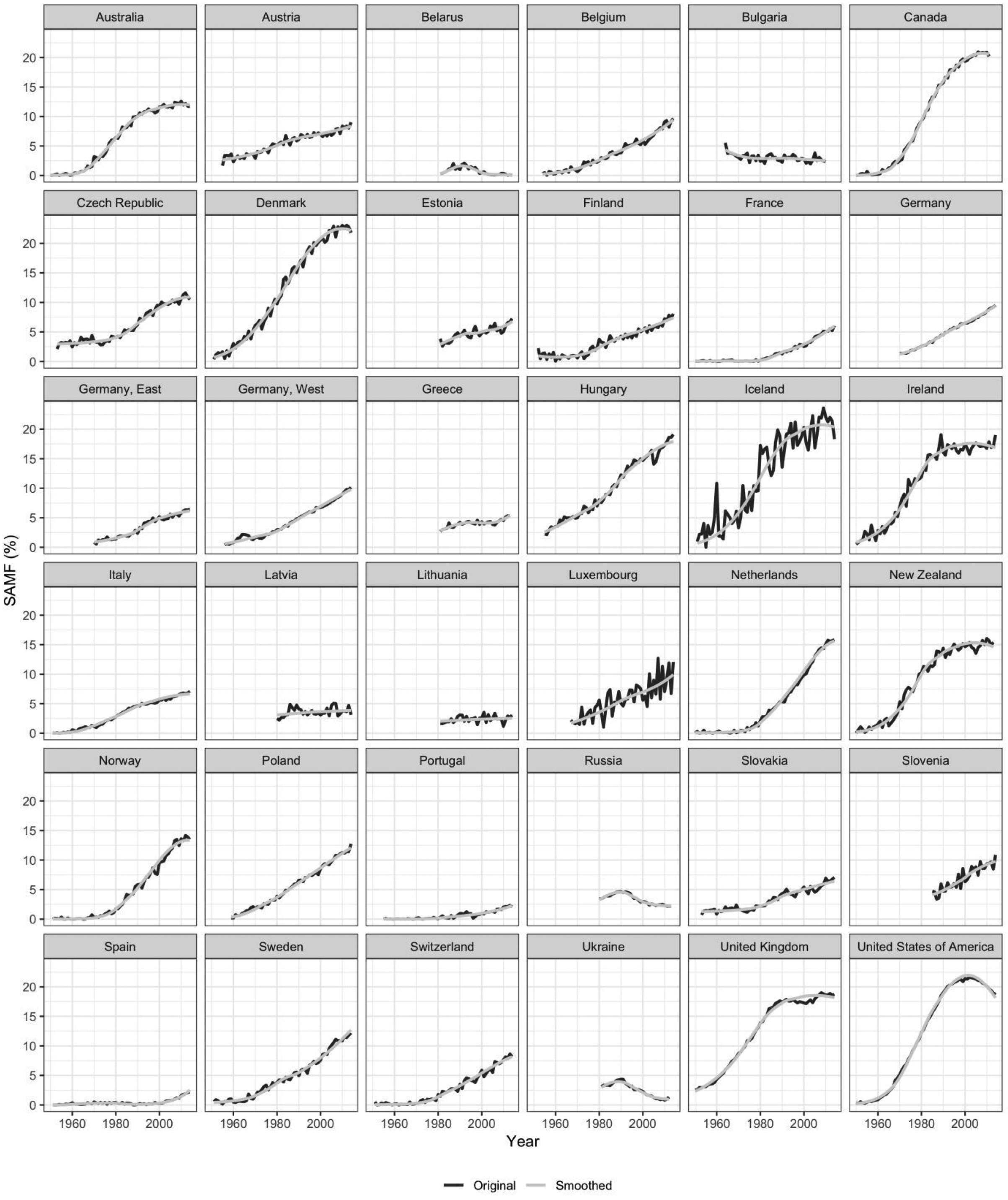
Country	Start year	End year	Additional data sources
Australia	1950	2014	
Austria	1955	2014	
Belarus	1981	2014	
Belgium	1954	2014	
Bulgaria	1964	2010	
Canada	1950	2011	
Czech Republic	1953	2014	For 1953–1985, lung cancer mortality data for the Czech Republic were estimated using data from WHOSIS on former Czechoslovakia.
Denmark	1951	2014	
Estonia	1981	2014	
Finland	1952	2014	
France	1950	2014	
Germany	1970	2014	
Germany, East	1970	2014	For 1970–1972, lung cancer deaths were obtained from the Archive DahlWitz Hoppegarten. For 1991–2014, lung cancer mortality data from www.gbe-bund were used.
Germany, West	1956	2014	For 1991–2014, lung cancer mortality data from www.gbe-bund were used.
Greece	1981	2013	
Hungary	1955	2014	
Iceland	1951	2014	
Ireland	1950	2014	
Italy	1951	2014	
Latvia	1980	2014	
Lithuania	1981	2014	
Luxembourg	1967	2014	
Netherlands	1950	2014	
New Zealand	1950	2013	
Norway	1951	2014	
Poland	1959	2014	
Portugal	1955	2014	Eurostat data were used to obtain lung cancer deaths for 2004–2006.
Russia	1980	2013	WHOSIS exposure data instead of HMD exposure data were used to calculate lung cancer mortality rates.
Slovakia	1953	2014	For 1953–1991, data for Slovakia were estimated using data from WHOSIS on former Czechoslovakia.
Slovenia	1985	2014	
Spain	1951	2014	
Sweden	1951	2014	
Switzerland	1951	2014	
Ukraine	1981	2012	
United Kingdom	1950	2014	Eurostat data were used to obtain lung cancer deaths for 2004–2006.
United States	1950	2014	

Appendix II. Trends over time in the smoothed smoking-attributable mortality fractions (SAMF) over ages 35–99, 4 North American/Australasian countries and 30 European countries, 1950–2014*, by sex and country. (a) Men, (b) women. *Or latest available year: Bulgaria (2010), Canada (2011), Greece (2013), New Zealand (2013), Ukraine (2012), Russia (2013).

a) Men



b) Women



References

1. World Health Organization. *WHO Global Report on Mortality Attributable to Tobacco*. Geneva: World Health Organization; 2012.
2. Rentería E, Jha P, Forman D, Soerjomataram I. The impact of cigarette smoking on life expectancy between 1980 and 2010: a global perspective. *Tob Control*. 2016;25(5):551–557.
3. Janssen F, Rousson V, Paccaud F. The role of smoking in changes in the survival curve: an empirical study in 10 European countries. *Ann Epidemiol.*. 2015;25(4):243–249.
4. Luy M, Wegner-Siegmundt C. The impact of smoking on gender differences in life expectancy: more heterogeneous than often stated. *Eur J Public Health*. 2015;25(4):706–710.
5. Rostron BL, Wilmoth JR. Estimating the effect of smoking on slowdowns in mortality declines in developed countries. *Demography*. 2011;48(2):461–479.
6. Preston SH, Glei DA, Wilmoth JR. Contribution of smoking to international differences in life expectancy. In: Crimmins EM, Preston SH, Cohen B, eds. *International Differences in Mortality at Older Ages—Dimensions and Sources*. Washington, DC: The National Academies Press; 2011:105–131.

7. Janssen F, Kunst AE, Mackenbach JP. Variations in the pace of old-age mortality decline among seven European countries, over the period 1950 to 1999: the role of smoking and factors earlier in life. *Eur J Popul*. 2007;23(2):171–188.
8. Pampel FC. Cigarette use and the narrowing sex differential in mortality. *Popul Dev Review*. 2002;28(1):77–104.
9. McCartney G, Mahmood L, Leyland AH, Batty GD, Hunt K. Contribution of smoking-related and alcohol-related deaths to the gender gap in mortality: evidence from 30 European countries. *Tob Control*. 2011;20(2):166–168.
10. Thun M, Peto R, Boreham J, Lopez AD. Stages of the cigarette epidemic on entering its second century. *Tob Control*. 2012;21(2):96–101.
11. Lopez AD, Collishaw N.E., Piha. T. A descriptive model of the cigarette epidemic in developed countries. *Tob Control*.. 1994;3(3):242–247.
12. Bilano V, Gilmour S, Moffiet T, et al. Global trends and projections for tobacco use, 1990-2025: an analysis of smoking indicators from the WHO comprehensive information systems for tobacco control. *Lancet*. 2015;385(9972):966–976.
13. Ng M, Freeman MK, Fleming TD, et al. Smoking prevalence and cigarette consumption in 187 countries, 1980-2012. *JAMA*. 2014;311(2):183–192.
14. Guindon GE, Boisclair D. *Past, Current and Future Trends in Tobacco Use. WHO Economic of Tobacco Control Paper 6*. Geneva: World Health Organization; 2003.
15. Bray FI, Weiderpass E. Lung cancer mortality trends in 36 European countries: Secular trends and birth cohort patterns by sex and region 1970-2007. *Int J Cancer*. 2010;126(6):1454–1466.
16. Zatonski WA, Manczuk M, Powles J, Negri E. Convergence of male and female lung cancer mortality at younger ages in the European Union and Russia. *Eur J Public Health*.. 2007;17(5):450–454.
17. Bosetti C, Levi F, Lucchini F, Negri E, La Vecchia C. Lung cancer mortality in European women: recent trends and perspectives. *Ann Oncol*. 2005;16(10):1597–1604.
18. Bray F, Tyczynski JE, Parkin DM. Going up or coming down? The changing phases of the lung cancer epidemic from 1967 to 1999 in the 15 European Union countries. *Eur J Cancer*. 2004;40(1):96–125.
19. Lopez AD. The lung cancer epidemic in developed countries. In: Lopez AD, Caselli G, Valkonen T, eds. *Adult Mortality in Developed Countries From Description to Explanation*. Oxford, England: Clarendon Press; 1995:111–134.
20. GBD 2015 Tobacco Collaborators. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the Global Burden of Disease Study 2015. *Lancet*. 2017;389(10082):1885–1906.
21. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1923–1994.
22. Stoeldraijer L, Bonneux L, van Duin C, van Wissen L, Janssen F. The future of smoking-attributable mortality: the case of England & Wales, Denmark and the Netherlands. *Addiction*. 2015;110(2):336–345.
23. Janssen F, van Wissen LJ, Kunst AE. Including the smoking epidemic in internationally coherent mortality projections. *Demography*. 2013;50(4):1341–1362.
24. Preston SH, Stokes A, Mehta NK, Cao B. Projecting the effect of changes in smoking and obesity on future life expectancy in the United States. *Demography*. 2014;51(1):27–49.
25. Pampel F. Forecasting sex differences in mortality in high income nations: the contribution of smoking. *Demogr Res*. 2005;13(18):455–484.
26. WHO Mortality Database. Health statistics and health information systems. Available at: www.who.int/healthinfo/statistics/mortality_rawdata/en/. Updated April 11, 2018.
27. Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at:www.mortality.org or www.humanmortality.de. Accessed August 27, 2018.
28. Peto R, Lopez AD, Boreham J, Thun M, Heath C Jr. Mortality from tobacco in developed countries: indirect estimation from national vital statistics. *Lancet*. 1992;339(8804):1268–1278.
29. Thun MJ, Day-Lally C, Myers DG, et al. Trends in tobacco smoking and mortality from cigarette use in Cancer Prevention Studies I (1959 through 1965) and II (1982 through 1988). In: Burns DM, Garfinkel L, Samet JM, eds. *Smoking and Tobacco Control Monograph 8: Changes in Cigarette-Related Disease Risks and Their Implications for Prevention and Control*. Bethesda, MD: National Cancer Institute; 1997:305–382.
30. Ezzati M, Lopez AD. Estimates of global mortality attributable to smoking in 2000. *Lancet*. 2003;362(9387):847–852.
31. Bianco E, Champagne B, Barnoya J. The tobacco epidemic in Latin America and the Caribbean: a snapshot. *Prev Control*. 2005;1(4):311–317.
32. Pampel FC. Divergent patterns of smoking across high-income nations. In: Crimmins EM, Preston SH, Cohen B, eds. *International Differences in Mortality at Older Ages*. Washington, DC: National Academies Press; 2010.
33. Janssen F, van Poppel F. The adoption of smoking and its effect on the mortality gender gap in Netherlands: a historical perspective. *Biomed Res Int*. 2015;2015:370274.
34. McKee M, Shkolnikov V. Understanding the toll of premature death among men in eastern Europe. *BMJ*. 2001;323(7320):1051–1055.
35. Perlman F, Bobak M, Gilmore A, McKee M. Trends in the prevalence of smoking in Russia during the transition to a market economy. *Tob Control*. 2007;16(5):299–305.
36. Institute for Health Metrics and Evaluation. Tobacco visualization. http://vizhub.healthdata.org/tobacco/. Updated 2017.
37. Cutler DM, Glaeser EL. Why do Europeans Smoke More Than Americans? NBER working paper series 12124. Massachussets: National Bureau of Economic Research; 2006.
38. Foulds J, Ramstrom L, Burke M, Fagerström K. Effect of smokeless tobacco (snus) on smoking and public health in Sweden. *Tob Control*. 2003;12(4):349–359.
39. Juel K. Increased mortality among Danish women: Population based register study. *BMJ*. 2000;321(7257):349–350.
40. Helweg-larsen K, Knudsen LB, Petersson B. Women in Denmark–why do they die so young? Risk factors for premature death. *Scand J Soc Welf*. 1998;7(4):266–276.
41. Pampel FC. Declining sex differences in mortality from lung cancer in high-income nations. *Demography*. 2003;40(1):45–65.
42. Byrnes JP, Miller DC, Schafer WD. Gender differences in risk taking: a meta-analysis. *Psychol Bull*.. 1999;125(3):367–383.
43. Waldron I. Trends in gender differences in mortality: relationships to changing gender differences in behaviour and other causal factors. In: Annandale E, Hunt K, eds. *Gender Inequalities in Health*. Buckingham, UK: Open University Press; 2000:150–181.
44. Oliveira AF, Valente JG, Leite IC. Aspects of tobacco attributable mortality: systematic review. *Rev Saude Publica*. 2008;42(2):335–345.
45. Pérez-Ríos M, Montes A. Methodologies used to estimate tobacco-attributable mortality: a review. *BMC Public Health*. 2008;8(22):1–11.
46. Preston SH, Glei DA, Wilmoth JR. A new method for estimating smoking-attributable mortality in high-income countries. *Int J Epidemiol*. 2010;39(2):430–438.
47. Rostron BL. A modified new method for estimating smoking-attributable mortality in high-income countries. *Demogr Res*. 2010;23(14):399–420.
48. Janssen F, Spriensma A. The contribution of smoking to regional mortality differences in the Netherlands. *Demogr Res*. 2012;27(9):233–260.
49. Tyczynski JE, Bray F, Parkin DM. Lung cancer in Europe in 2000: Epidemiology, prevention, and early detection. *Lancet Oncol*. 2003;4(1):45–55.
50. Levi F, La Vecchia C, Lucchini F, Negri E. Lung cancer in Icelandic women. *Eur J Cancer Prev*. 1999;8(4):369.